From Stars to Brains: Milestones in the Planetary Evolution of Life and Intelligence

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Arthur Glikson
1911 - 1966

The book is dedicated to Arthur Glikson, my late father, an architect, town planner and pioneer of ecological and regional planning

Preface

The whole is greater than the sum of its parts

Aristotle

Who knows for certain?
Who shall here declare it?
Whence was it born, whence came creation?
The Gods are later than this world's formation;
Who then can know the origins of the world?

The Rig Veda, X.129

This treatise aims at exploring individual and swarm behaviour patterns which potentially hint at as yet-unexplained biological principles and laws of complexity. It includes an overview of theories on the evolution of life (Heron and Freeman 2013; Zimmer and Emlen 2015; Futuyma and Kirkpatrick 2017) with perspectives from the earth sciences, commencing with the earliest observed records of life, followed by reviews and discussion of the building blocks of life, the arthropods, deep sea communities associated with hydrothermal springs, the evolution of the eye, the birds and finally of humans and the directionality of evolution. The permutation of basic atoms—carbon, oxygen, hydrogen, nitrogen and sulphur—into the biomolecules Deoxyribonucleic acid (DNA)[1] and Ribonucleic acid (RNA)[2], which subsequently evolved into cells and the brains, defining the origin or life and of intelligence, remains unexplained by the known laws of physics, nor is the source of the information contained in the basic biomolecules. In so far as it can be expected that life would continue to be formed from inorganic molecules, had this process operated at present it could have been more readily identified. Aristotle's dictum of "*the whole is greater than the sum of the parts*", pertaining to the

[1]A molecule composed of two chains (made of nucleotides) which coil around each other to form a double helix carrying the genetic instructions used in the growth, development, functioning and reproduction of all known living organisms and many viruses.

[2]Ribonucleic acid (RNA) is a polymeric molecule essential in various biological roles in coding, decoding, regulation, and expression of genes.

evolution of multicomponent cells, swarm behaviour, Niels Bohr's theory of holism[3] or Ellis' (2012) theory of top to down causality, remains to be further explored, possibly furnishing essential keys for unknown physical laws that govern the appearance and evolution of life.

Inherent in the question of the origin of life is an ***anthropocentric bias***, related to the self-referential ***Anthropic Principle***[4] and early views of man's supposed dominion over all other species[5], namely the polarity between animal and human faculties manifested in ancient scripts. In terms of the anthropocentric bias, humans can think but animals act by instinct. However, this bias is contradicted by large bodies of evidence, some of which are considered in this book. A critical exception being that of *Homo sapiens*, having mastered the ignition of fire and splitting of the atom, leading to the Seventh mass extinction of species.

The *Anthropic Principle*, however should be capable of being circumvented using the scientific falsification method[6], applying independently verified constants of physics, including gravity, the speed of light, the universe expansion rate and age since the Big Bang—observations with which inhabitants on other planets may concur?

Central to Darwin and Wallace's theory of evolution is the directionality arising from mutations induced by external environmental events and inter-species competition, such as changes in climate and solar and cosmic radiation, followed by preferential natural selection of adaptable organisms. On the other hand questions inherent in the evolution of intelligence, in particular of purposeful thinking, remain little resolved. As distinct from Darwinian natural selection and survival of the fittest principles, the intelligent probes of humans and animals constitute directional trajectories influenced by both external circumstances and internal pressures. It is far from clear how thought processes, facilitated by neuron networks, leading to purposeful proactive trajectories, arise from natural selection.

The narrative of the book focuses on behaviour patterns of life forms, from individual cells to colonial life, from the genetic code to collective brains and swarm intelligence, including that of the termites, bees and Avian birds, the descendants of the Archosauria[7] (dinosaurs). It touches on fundamental questions:

[3] https://arxiv.org/ftp/arxiv/papers/1608/1608.00205.pdf.

[4] The Anthropic principle: A philosophical consideration that observations of the universe must be compatible with the conscious and sapient life that observes it. Some proponents of the anthropic principle reason that it explains why this universe has the age and the fundamental physical constants necessary to accommodate conscious life. As a result, they believe it is unremarkable that this universe has fundamental constants that happen to fall within the narrow range thought to be compatible with life. https://en.wikipedia.org/wiki/Anthropic_principle.

[5] As stated: "*Then God said, Let us make mankind in our image, in our likeness, so that they may rule over the fish in the sea and the birds in the sky, over the livestock and all the wild animals, and over all the creatures that move along the ground*." (Genesis 1:26).

[6] A statement, hypothesis, or theory has falsifiability (or is falsifiable) if it can be proven false by contradicting it with a basic statement or observation.

[7] http://www.ucmp.berkeley.edu/diapsids/archosauria.html.

how have living cells come to contain diverse multi-tasked elements of *hardware* such as the nucleus, nucleolus, ribosomes, mitochondrion, endoplasmic reticulum, golgi bodies, centrosome, vacuole, lysosome and so on, coordinated for multi-tasked functions by a living *software*? Fundamental questions arise: how can the cell, a brain and an organism, evolve through a series of accidental genetic mutations, random environmental changes and natural selection, engage in purposeful design of complex technical and social systems, as is the case with colonial arthropods or human civilization? Are unknown laws of self-organization and complexity at work?[8] The genius of Darwin himself recognized that the evolution of a complex system, such as the eye, is not readily explained by the theory of evolution, stating "*it was absurd to propose that the human eye evolved through spontaneous mutation and natural selection*".[9] Kaufmann (1993) suggested that, in order to explain the evolving self-generated architecture of living organisms yet unexplained processes must exist, supplementing Darwinian evolution theory and existence of *biological determinism*.[10] In discussing *biological determinism* Davies (2000a, b) considers this option, while true, cannot be implied by the known laws of physics and chemistry alone and that additional discoveries or principles may be found in the emerging sciences of complexity and information theory. Such principles appear to govern human civilizations, with the remarkable phenomenon of the human mastery of fire, which allowed the genus *Homo* to reach major technical and cultural developments. It appears human intellect and science have not reached a stage allowing answers to these fundamental questions.

Canberra, Australia Andrew Y. Glikson

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[8] https://en.wikipedia.org/wiki/Non-Darwinian_Evolution_(paper).

[9] https://www.nature.com/news/2008/081119/full/456304a.html.

[10] Biological determinism, also called biologism or biodeterminism, the idea that most human characteristics, physical and mental, are determined at conception by hereditary factors passed from parent to offspring.

Kaufmann SA (1993) The origins of order: self-organization and selection in evolution, 1st edn. https://www.amazon.com/Origins-Order-Self-Organization-Selection-Evolution/dp/0195079515

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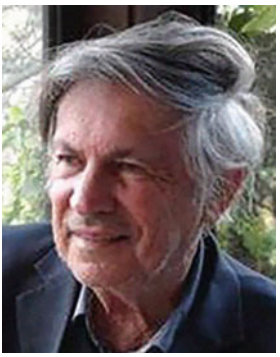

Andrew Y. Glikson an Earth and paleo-climate scientist, studied geology at the University of Jerusalem and graduated at the University of Western Australia in 1968. He conducted geological and geochemical surveys of the oldest geological formations in western and central Australia, South Africa, India and Canada; studied large asteroid impacts, including effects on the atmosphere, oceans and mass extinction of species. Since 2005 he studied the relations between climate and human evolution. He was active in communicating nuclear and climate change evidence to the public and parliament through papers, lectures, conferences and presentations.

Contributed Books List

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Introduction: The Origin of Intelligence

My suspicion is that the universe is not only queerer than we suppose, but queerer than we can suppose.

J. B. S. Haldane

Life, synonymous with natural intelligence[11], is everywhere, from primary DNA-RNA molecules all the way to the brain, on every scale from microns to mega-cities, including individual intelligence (Fig. 1) and collective swarm intelligence of species. Advanced life, representing transient reversal of entropy inherent in the second law of thermodynamics (Malley et al. 2016), is believed to have emerged on Earth at least $\sim 500.10^6$ years, following planetary accretion about $4.54 \times 10^9 \pm 1\%$ years-ago.[12] No one knows where intelligence comes from nor, along with Darwinian evolution, is it clear how intelligence has evolved. The origin and evolution of living forms are closely related to and reflect the milieu in which they have emerged, rendering studies of the physical and chemical nature of their surrounds closely relevant to the question. According to Davies (2000a, b) and (Rees 2017) the universe appears to be hospitable to life, or bio-friendly, a possibly unique condition among cosmic realms in a *multiverse*[13], an ensemble of universes most of which may be sterile. On Earth, the initial condition for life almost certainly required a presence of water, allowing microbes a source of energy by breaking down H_2O molecules and combining oxygen and hydrogen ions with metals as a source of energy.[14]

The initial conditions that allowed synthesis of the early bio-molecules are not known, nor whether such biogenetic conditions persisted. The likelihood that the laws which govern life are written into nature, allowing life to emerge under suitable conditions, remains undefined. The question is whether life sprang by

[11] Intelligence, the subject of a cultural and philosophical bias, is defined by the "The ability to learn or understand or to deal with new or trying situations or the ability to apply knowledge to manipulate one's environment".

[12] Age of the Earth (2007) USGS https://pubs.usgs.gov/gip/geotime/age.html.

[13] The Multiverse. Last edited 20 July 2018 https://en.wikipedia.org/wiki/Multiverse.

[14] Solar fuels as generated by nature https://www.mpg.de/8373743/photosynthetic-water-splitting.

Fig. 1 Intelligence is everywhere. The human-like face of a fruit fly. Nature Picture Library. Fruit flies (Drosophila melanogaster) have a kind of mind's eye (© Solvin Zankl/naturepl.com, reprinted with permission). http://www.bbc.com/earth/story/20170123-how-insects-like-bumblebees-do-so-much-with-tiny-brains

chance or, alternatively, as a function of unknown laws of physics. The synthesis and growth of bio-molecules on the surfaces of planets face formidable hazards, from a lack of water, cosmic radiation, meteorite and asteroid impacts, and volcanic activity. Sources of energy for life processes vary from photosynthesis[15] at surface or near-surface levels, to microbial-facilitated oxidation/reduction reactions[16] around deep sea hydrothermal vents.

The question is whether life has originated at one point in time or, alternatively, repeatedly emerged through multiple geneses (Davies 2000a, b). Following in the steps of Darwinian evolution the growth of integrated complex systems, from individual cells to the brain to swarm intelligence, pose yet-unanswered questions. Concepts such as *emergent properties*, *intelligent design*, fractal theory or algorithms of life, relevant to the principles of animation and structural patterns, regularities and proliferation, are not readily integrated with Darwinian evolution theory. Questions remain hardly answered regarding the origin of highly complex

[15] Photosynthesis is a process used by plants and other organisms to convert light energy into chemical energy that can later be released to fuel the organisms' activities (energy transformation). This chemical energy is stored in carbohydrate molecules, such as sugars, which are synthesized from carbon dioxide and water.

[16] Oxidation is the loss of electrons or an increase in oxidation state by a molecule, atom, or ion. Reduction is the gain of electrons or a decrease in oxidation state by a molecule, atom, or ion.

information storage and multiplication systems facilitated by the DNA, RNA, ribosome[17] and other biomolecules. How has the complex multi-component and multi-tasked machinery of the living cell, containing diverse elements such as nucleus, nucleolus[18], ribosomes, mitochondrion[19], endoplasmic reticulum[20], golgi bodies[21], centrosome[22], vacuole[23], lysosome[24] and so on, evolved through random processes? What roles are played by genes[25] and what by *learnt behaviour*? Does human cultural evolution represent the successor of biological evolution? How can the cell or an organism, evolved through a series of accidental genetic mutations, random environmental events and natural selection engage in purposeful or directional design of complex technical and social systems? What are the origins of directional purposeful thinking processes? How can computer-like biological systems be constructed without an intelligent plan? The answers may evade the human mind. Is it possible that intellect and science have not developed to a stage allowing answers to these questions?

Directionality of evolution may be accounted for by natural selection of relatively adaptable collective behaviour of organisms, however a fundamental enigma pertains to the possible existence of a vector of *purpose*, *intention* or *directionality* in the behaviour of individual organisms and cooperative colonies. The development of the *hardware* and *software*[26] of multi-component systems, such as cell, the

[17]A minute particle consisting of RNA and associated proteins found in large numbers in the cytoplasm of living cells. They bind messenger RNA and transfer RNA to synthesize polypeptides and proteins.

[18]A small dense spherical structure in the nucleus of a cell during interphase.

[19]Membrane-bound organelle found in the cytoplasm of almost all eukaryotic cells (cells with clearly defined nuclei), the primary function of which is to generate large quantities of energy in the form of adenosine triphosphate (ATP). Mitochondria are typically round to oval in shape and range in size from 0.5 to 10 μm. In addition to producing energy, mitochondria store calcium for cell signalling activities, generate heat, and mediate cell growth and deat.

[20]A network of membranous tubules within the cytoplasm of a eukaryotic cell, continuous with the nuclear membrane. It usually has ribosomes attached and is involved in protein and lipid synthesis.

[21]A complex of vesicles and folded membranes within the cytoplasm of most eukaryotic cells, involved in secretion and intracellular transport.

[22]An organelle that is the main place where cell microtubules are organized. Also, it regulates the cell division cycle, the stages which lead up to one cell dividing in two.

[23]A membrane-bound organelle which is present in all plant and fungal cells and some protist, animal [1] and bacterial cells. [2] Vacuoles are essentially enclosed compartments which are filled with water containing inorganic and organic molecules including enzymes in solution, though in certain cases they may contain solids which have been engulfed. Vacuoles are formed by the fusion of multiple membrane vesicles and are effectively just larger forms of these.

[24]An organelle in the cytoplasm of eukaryotic cells containing degradative enzymes enclosed in a membrane.

[25]A basic physical and functional unit of heredity. Genes, which are made up of DNA, act as instructions to make molecules called proteins. In humans, genes vary in size from a few hundred DNA bases to more than 2 million bases.

[26]Hardware: the physical machinery and devices that make up a computer system. Software: the programs and instructions used to run the system.

eye, insect colonies and human civilization, may be facilitated by factors further than natural selection? In terms of *the whole being greater than the sum of the parts*, the selfish gene theory Dawkins (2006) can hardly be reconciled with evidence for whole-cell synergy and intra-cell and inter-cell intelligence of complex life forms. In terms of the principle of the *survival of the fittest*, there are difficulties in reconciling mathematical modelling with perceived vectors of evolutionary purpose or directionality, for example the evolution of centrally controlled intelligent communities such as bee hives, termite nests and human civilizations.

Through geological time gradual evolution has been interrupted by episodes of mass extinction of species triggered by impact of large asteroids, volcanic eruptions, methane release, extreme glaciations and other factors, disrupting long-term evolutionary cycles (Keller 2005).[27] It is not clear how the *molecular clock*, namely the regular mutation rate of nucleotide sequences used to deduce time, can be reconciled with the biological effects of random external events.[28]

The concept of panspermia, namely interstellar transport of biomolecules associated with cometary dust and vapor, or within meteorites (Hoyle and Wickramasinghe 1977), remains unconfirmed, although possible evidence by Callahan et al. (2011) for nucleobases, including adenine, guanine, xanthine, hypoxanthine and purine in carbonaceous chondrites, could suggest synthesis of biomolecules in asteroids parent bodies? Transpermia, the transport of microbes between planets, is supported by the discovery of Martian meteorites on Earth.[29] While this may defer the question of the origin of life one step further in time and space, it does not contradict terrestrial biogenesis, nor does it explain biogenesis. Fundamental questions remain. Can intelligence emerge through a series of mutations, natural selection and coincidences? How can the rapid appearance of high intelligence, represented for example by the advent of human cave painting and ornamentation since about 35,600 years ago[30] (Fig. 2)—a blip in the evolutionary record—be explained in terms of Darwinian principles.

[27] https://www.tandfonline.com/doi/abs/10.1080/08120090500170393.

[28] https://www.sciencedirect.com/science/article/pii/S0960982216303165. In the 1960s, several groups of scientists, noted that proteins experience amino acid replacements at a surprisingly consistent rate across very different species. This presumed single, uniform rate of genetic evolution was subsequently described using the term 'molecular clock'. Biologists quickly realized that such a universal pacemaker could be used as a yardstick for measuring the timescale of evolutionary divergences: estimating the rate of amino acid exchanges per unit of time and applying it to protein differences across a range of organisms would allow deduction of the divergence times of their respective lineages.

[29] Mars Meteorites. 1996-2006. NASA Jet Propulsion Laboratory, California Institute of Technology. https://www2.jpl.nasa.gov/snc/index.html.

[30] Oldest cave painting in the world http://www.oldest.org/artliterature/cave-paintings/.

Fig. 2 Detail of a bison in the cave at Altamira, 35,600 years-old, in northern Spain, discovered within the 19th century. By Museo de Altamira y D. Rodríguez, https://commons.wikimedia.org/w/index.php?curid=24512679 licensed under CC BY-SA 3.0

A plethora of studies exist concerned with the origin of life[31], including theories of an "RNA world"[32], "metabolism first"[33] and others.[34] Experimental studies with implications for the origin of life, such as by Sutherland (2017)[35], have not to-date resolved the source of information leading to formation of biomolecules, as stated: "*To proceed from simple feedstock molecules and energy sources to a living system requires extensive synthesis and coordinated assembly to occur over numerous steps, which are governed only by environmental factors and inherent chemical reactivity. Demonstrating such a process in the laboratory would show how life can start from the inanimate. If the starting materials were irrefutably primordial and the end result happened to bear an uncanny resemblance to extant biology—for what turned out to be purely chemical reasons, albeit elegantly subtle ones—then it could be a recapitulation of the way that natural life originated. We are not yet close to achieving this end, but recent results suggest that we may have nearly finished the first phase: the beginning*".

[31] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4683543/.

[32] https://www.ncbi.nlm.nih.gov/books/NBK26876/.

[33] http://sciencecases.lib.buffalo.edu/cs/files/origins_debate_intro.pdf.

[34] https://gabrielledallman.wordpress.com/2016/10/15/metabolism-first-vs-replication-first.

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